Investigative case studies: Initial results

UNIBO- Silvia Zaoli

Founding Members
EUROPEAN UNION EUROCONTROL

Flight Arrival Coordination (FAC)

Differences between levels of implementation

- Level 0: EAMAN minimises arrival delay
- Level 1: EAMAN minimises reactionary delays
- Level 2: EAMAN minimises airlines' costs

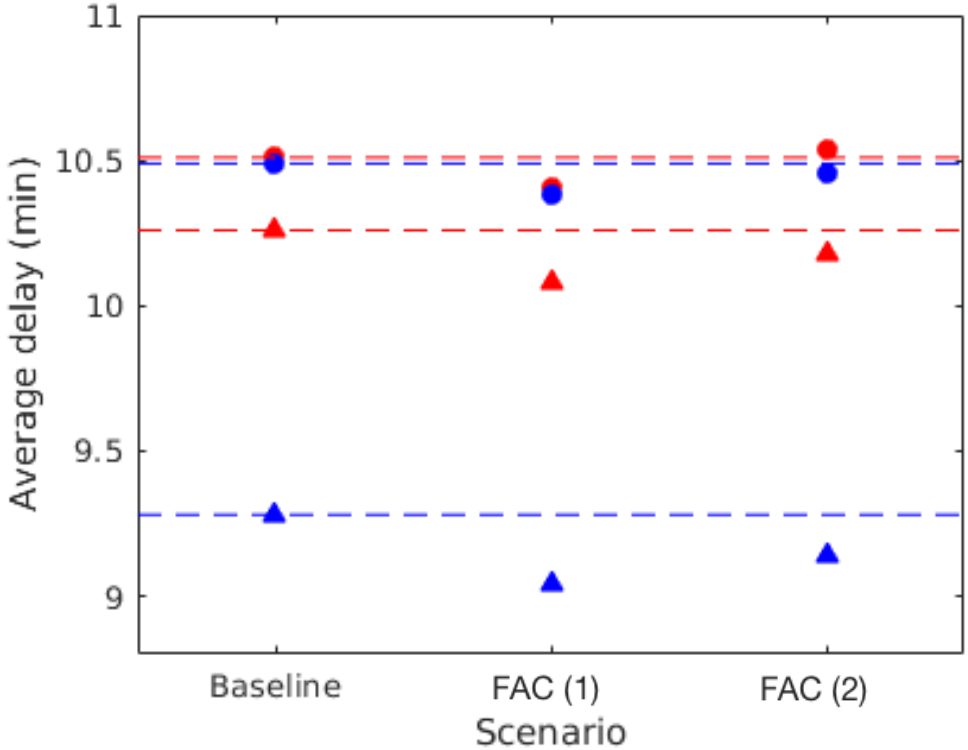
Slight decrease at level 1

Smaller decrease at level 2

Delays

Default case:

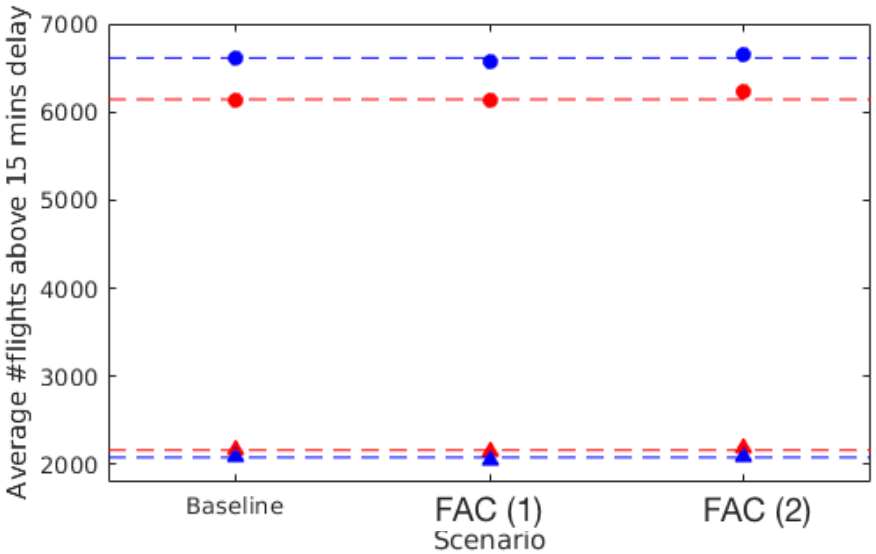
- Departure delay
- Arrival delay (early arrivals counted as zero delay)
- Departure delay of flights arriving in FAC airports
- Arrival delay of flights arriving in FAC airports

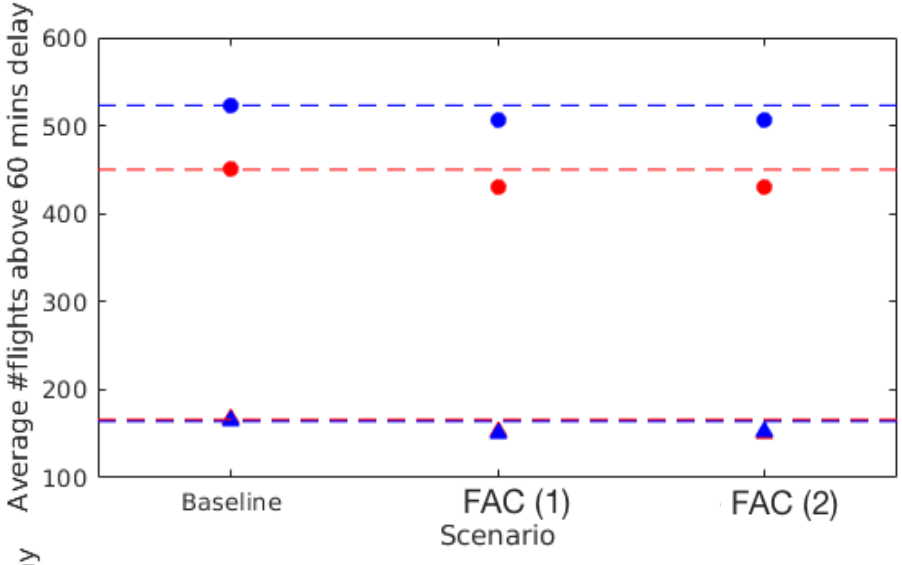


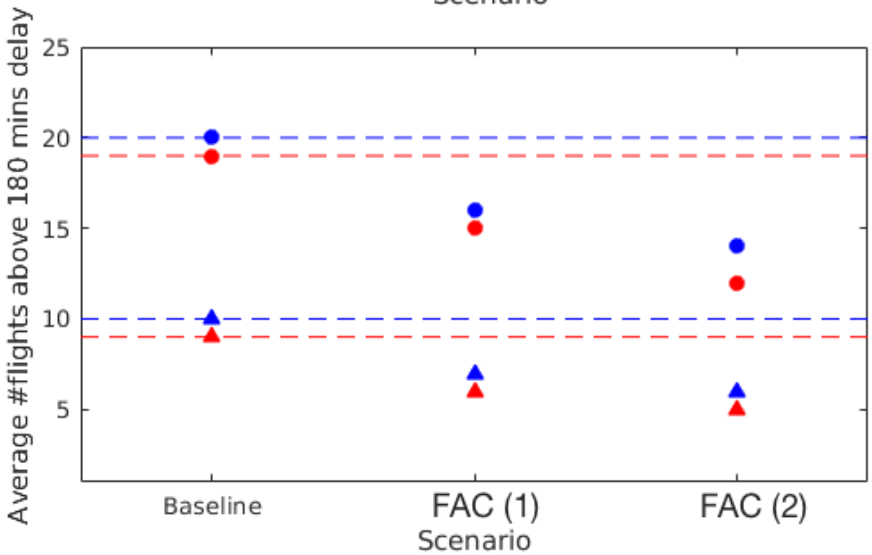
Flight Arrival Coordination (FAC)

Delays -TAILS

Default case:







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Flight Arrival Coordination (FAC)

Delays -TAILS

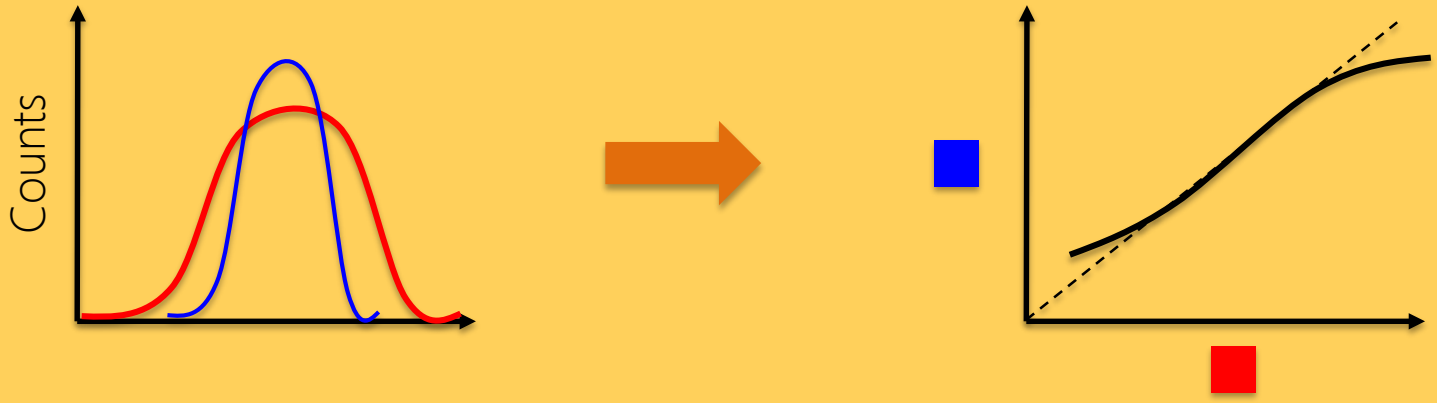
Average delay decreases very slightly, but we see an improvement in the tails.

Another way to see the change in tails thickness:

QQ-plots

Plot of n-th quantile of sample 1 against n-th quantile of sample 2

E.g., sample 1= departure delays in the baseline,
sample 2 = departure delays in FAC level 1



Flight Arrival Coordination (FAC)

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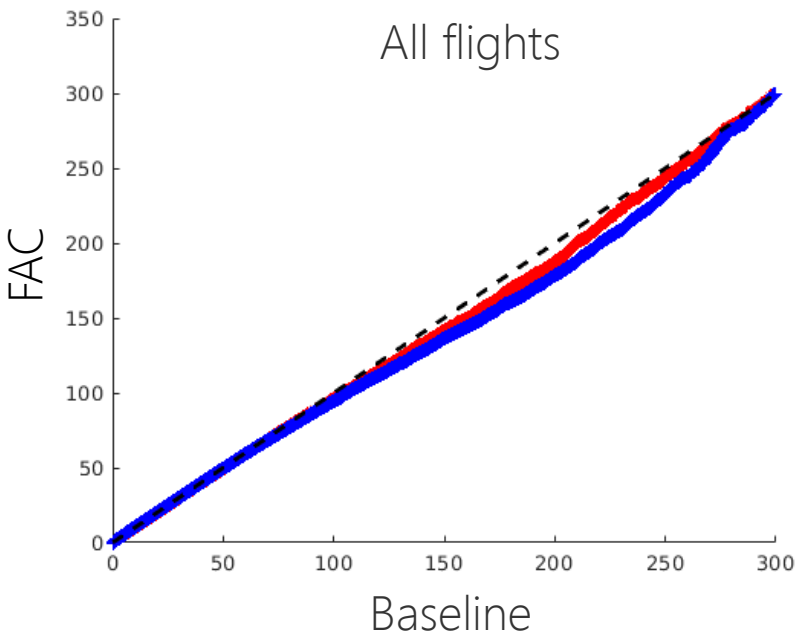
Flight Arrival Coordination (FAC)

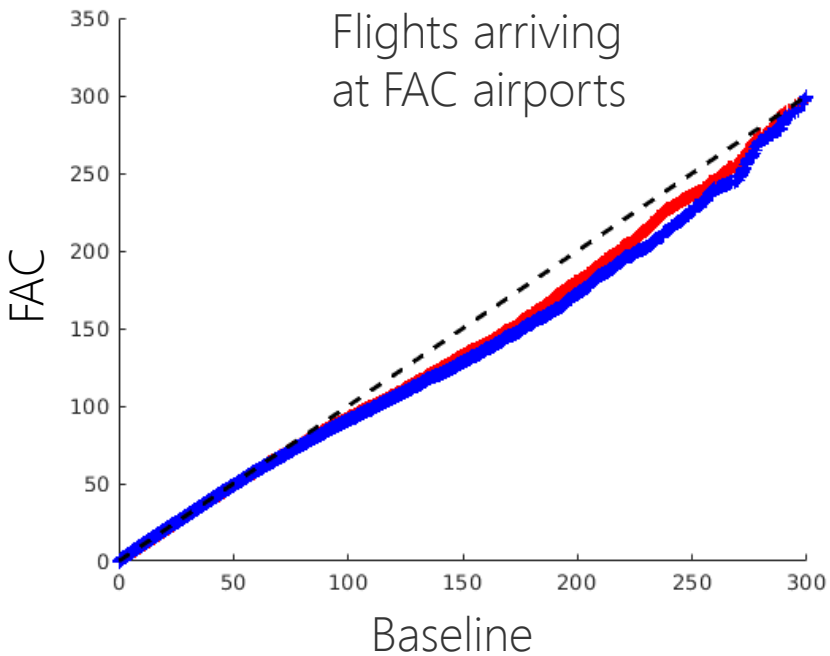
Delays -TAILS

QQ-plots of departure delay:

Level 1

Level 2





Thinner tail above ~100 minutes: the mechanism is effective in avoiding very large delays!

Flight Arrival Coordination (FAC)

Delays

For the stressed case:

- No average decrease of delays
- No decrease of number of delays in the tails (actually, slight increase)
- No effect observed in the QQ-plots

Why ?

Flight Arrival Coordination (FAC)

Costs

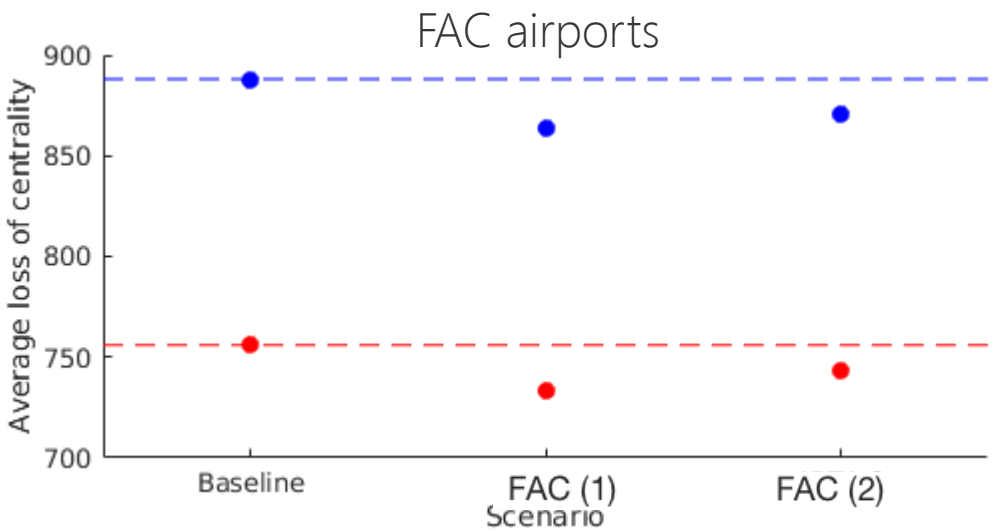
What costs do you expect to change?

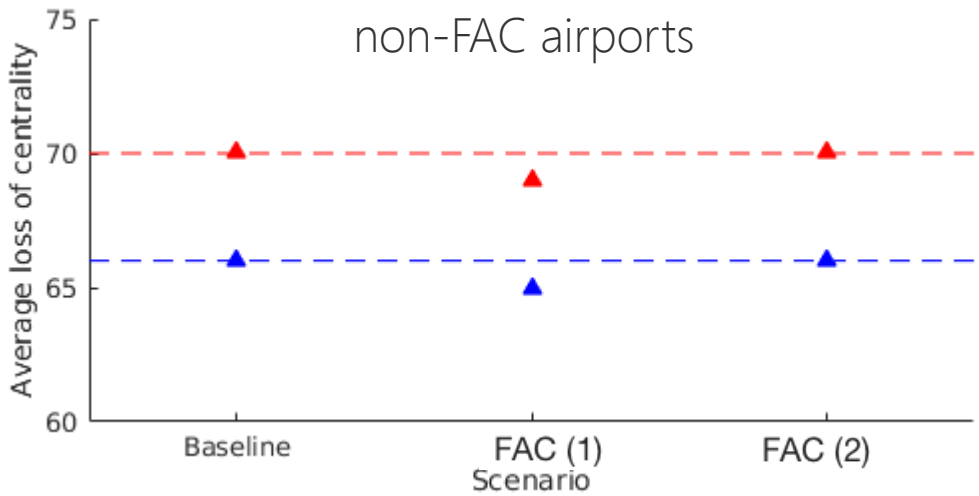
- Fuel? No changes
- Compensation? Slight decrease in the average
- Transfer? Slight decrease in the fraction of flights that pay transfer costs
- Duty of care? Slight decrease in the fraction of flights that pay doc
- Non-passenger costs? Slight increase
- Total cost? No significant changes

Flight Arrival Coordination (FAC)

Passenger Centrality

For the stressed case:





Loss of passenger centrality
measure of the number of passengers' itineraries disrupted (incoming or outgoing)

- Loss of outgoing PC
- Loss of incoming PC

In the default case no improvement (rather, an increased centrality loss at level 2)

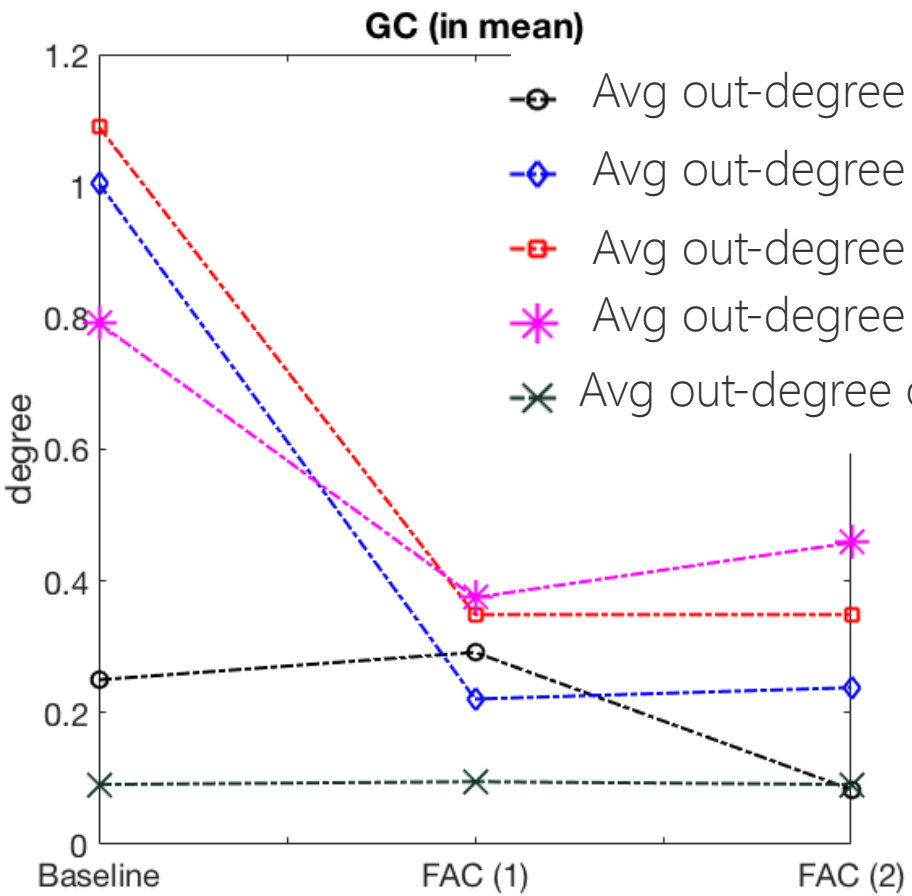
Why more PC losses at level 2?

Flight Arrival Coordination (FAC)

Delay causality

Out-degree in causality network

Each airport is a node, link from i to j when delays in i cause delays in j



- Avg out-degree of FAC airp. towards FAC airp.
- Avg out-degree of non-FAC airp. towards non-FAC airp.
- Avg out-degree (entire network)
- Avg out-degree of FAC airp. towards non-FAC airp.
- Avg out-degree of non- FAC airp. towards FAC airp.

- Considering the entire network, the average degree decreases with FAC at levels 1 and 2 (same)
- Causation among airports with FAC increases at level 1, but decreases at level 2
- Causation from airports with FAC to airports without decrease (more with level 1)
- Causation among airports with no FAC decreases

Flight Arrival Coordination (FAC)

Delay causality

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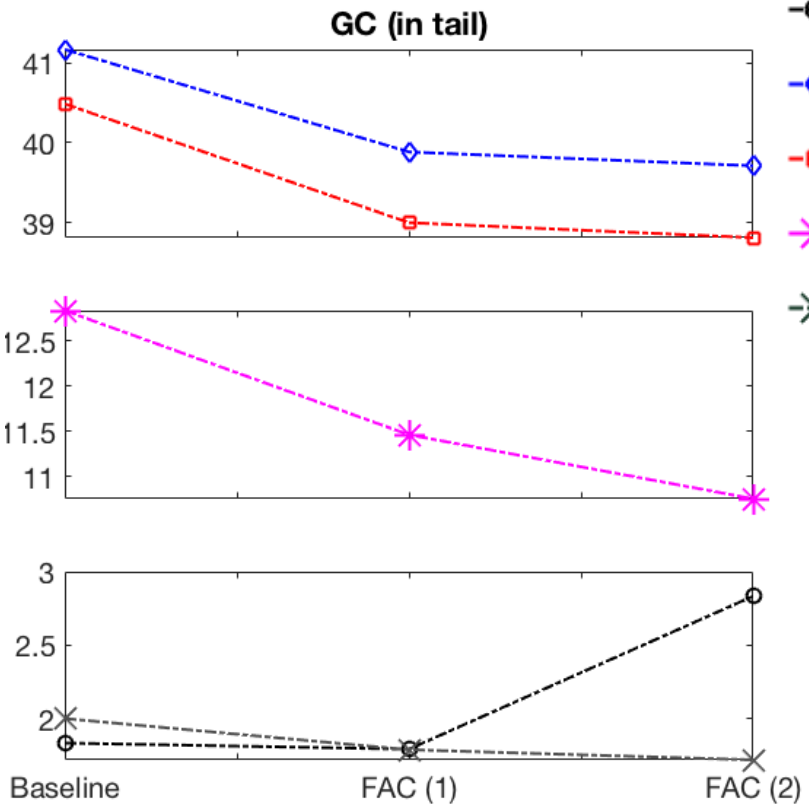


- Avg out-degree of FAC airp. towards FAC airp.
- Avg out-degree of non-FAC airp. to non-FAC airp.
- Avg out-degree (entire network)
- Avg out-degree of FAC airp. towards non-FAC airp.
- Avg out-degree of non- FAC airp. towards FAC airp.

- Level 2 now shows lower degrees than level 1, except among FAC
- Meaning: with level 2, more propagation of extreme delays among FAC airports, but less towards the rest of the network and overall

Flight Arrival Coordination (FAC)

Conclusions

- In the default case, less delays in the tails
- No impact on the total costs
- Less delay causality links (less delay propagation)
- However, no improvement from the passengers' point of view (even a worsening at level 2)

- In the stressed case, no effect on the delays
- No impact on the total costs
- Causality: no results yet
- Decreased disruption of passengers' itineraries (better at level 1 than 2)

4D Trajectory adjustment

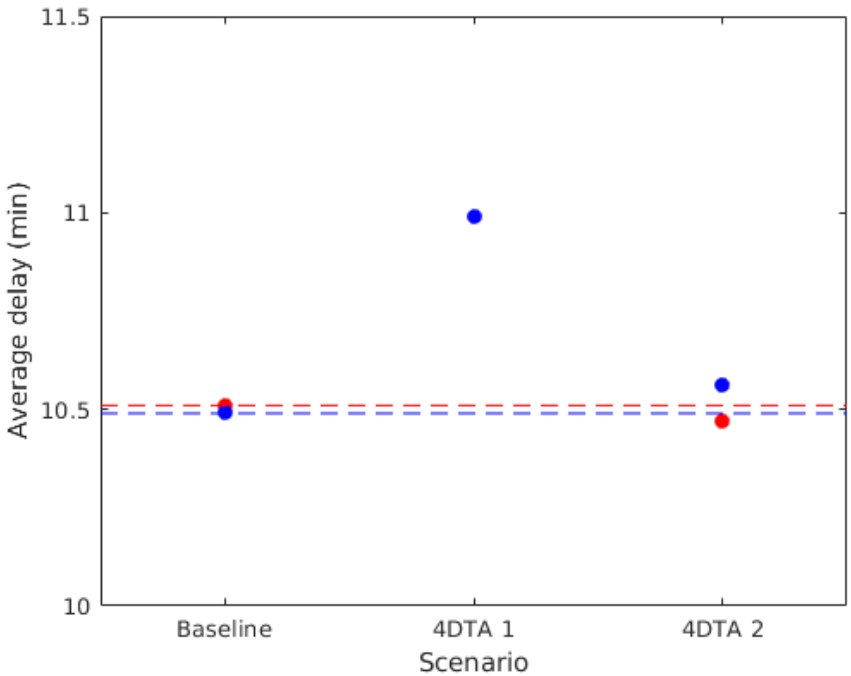
Differences between levels of implementation

- Level 0: delay>15 mins is recovered with probability increasing linearly with the delay, wait for passengers only for FLEX an up to 15 mins
- Level 1: Wait for passengers and speed adjusting evaluated INDEPENDENTLY before departure, assessing cost of each decision
- Level 2: Evaluated together before departure, speed adjusting evaluated again at TOC

Delays

In the default case:

- Departure delay
- Arrival delay (early arrivals counted as zero delay)

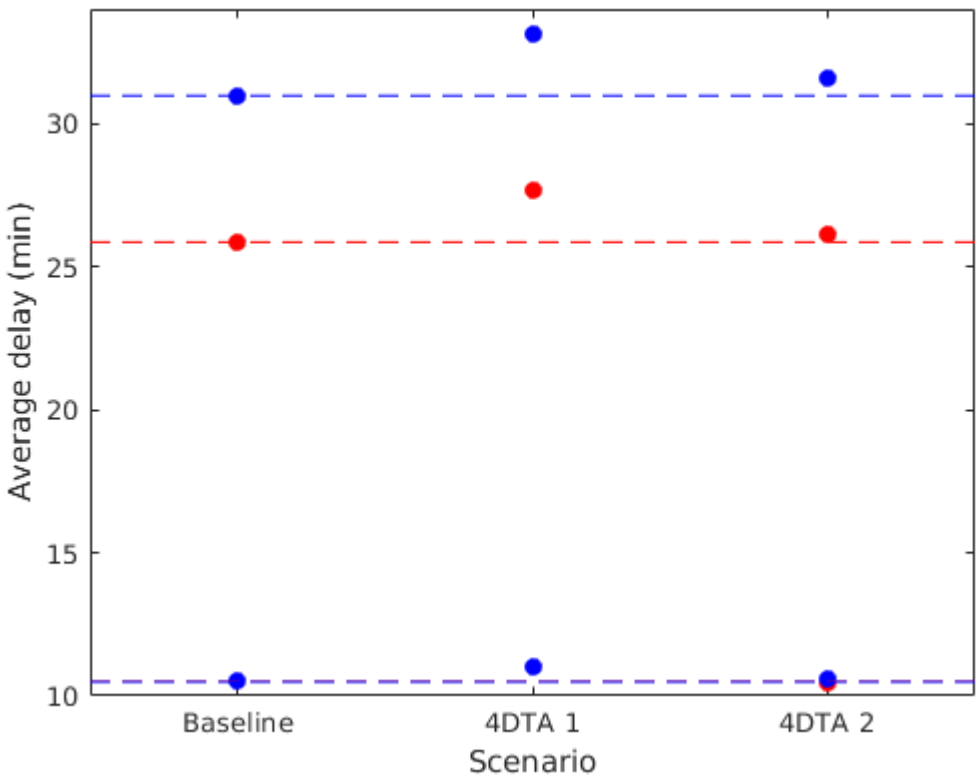


- Slight increase (especially at level 1) or remains the same

4D Trajectory adjustment

Delays

In the stressed case:



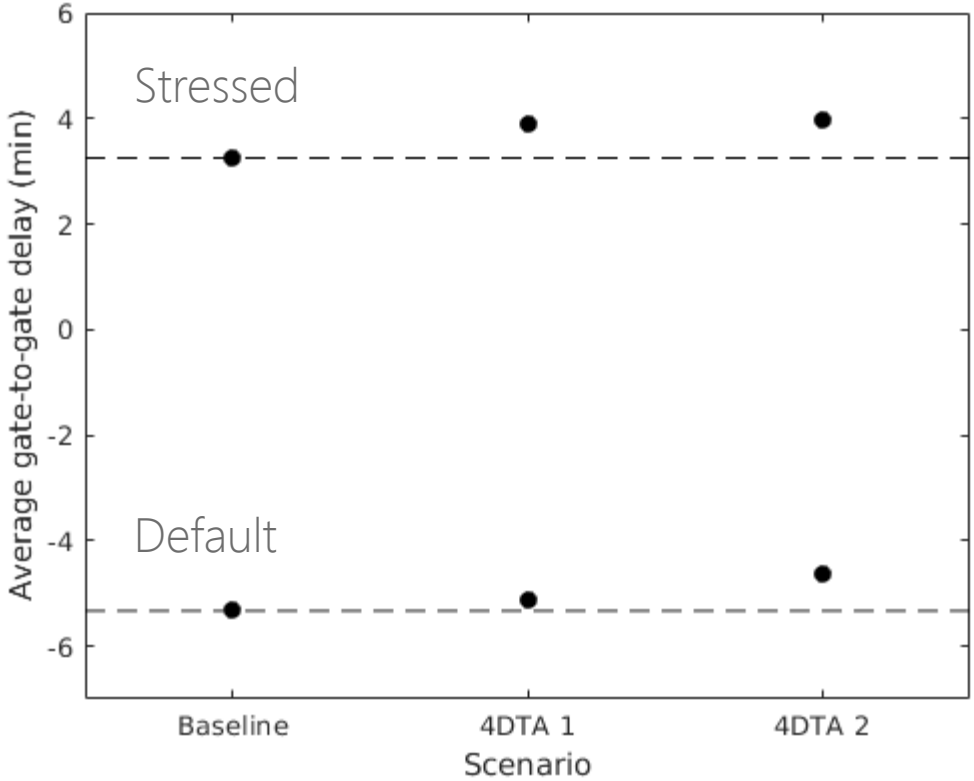
- Departure delay
- Arrival delay (early arrivals counted as zero delay)

- Delays increase
- They increase less in level 2

Why do delays increase?

4D Trajectory adjustment

Delays

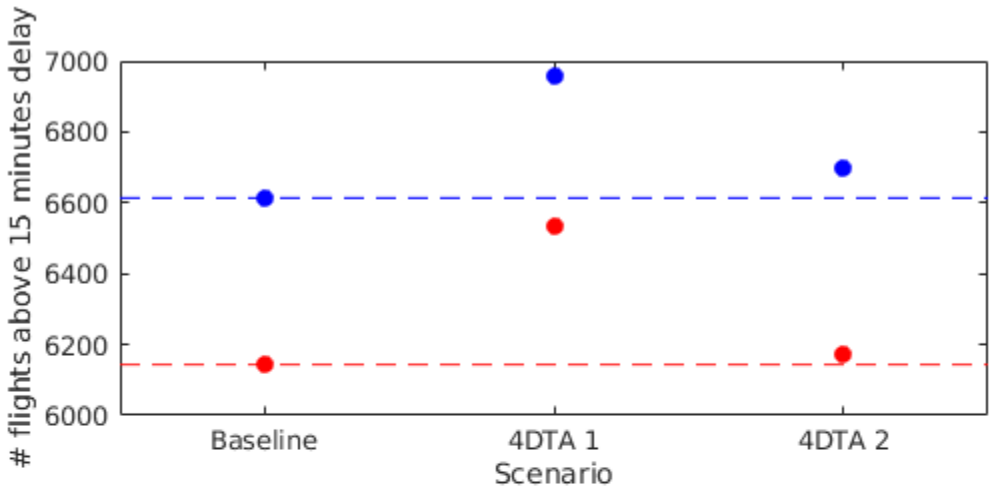


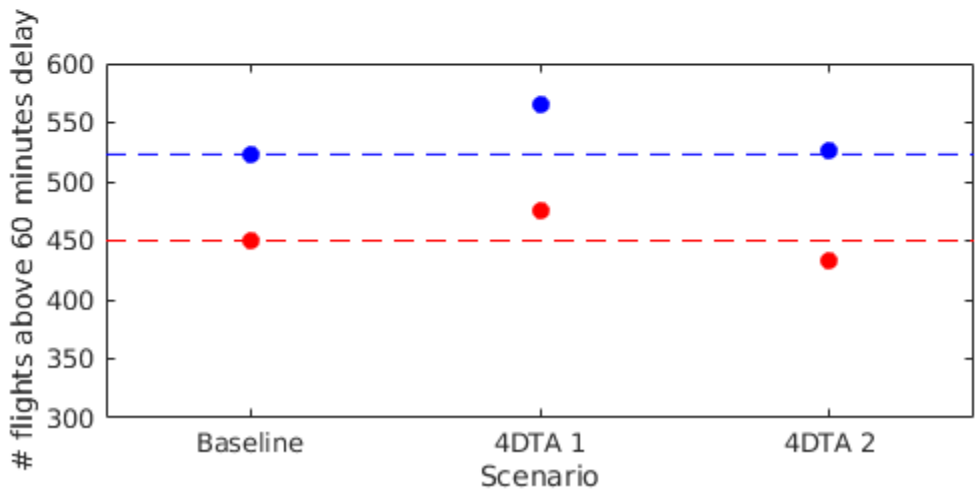
- Gate-to-gate delay increases
- Less speeding up with respect to the baseline might explain increase of delays (as confirmed by costs, see next slides)

4D Trajectory adjustment

Delay -Tails

In the default case:





- Departure delay
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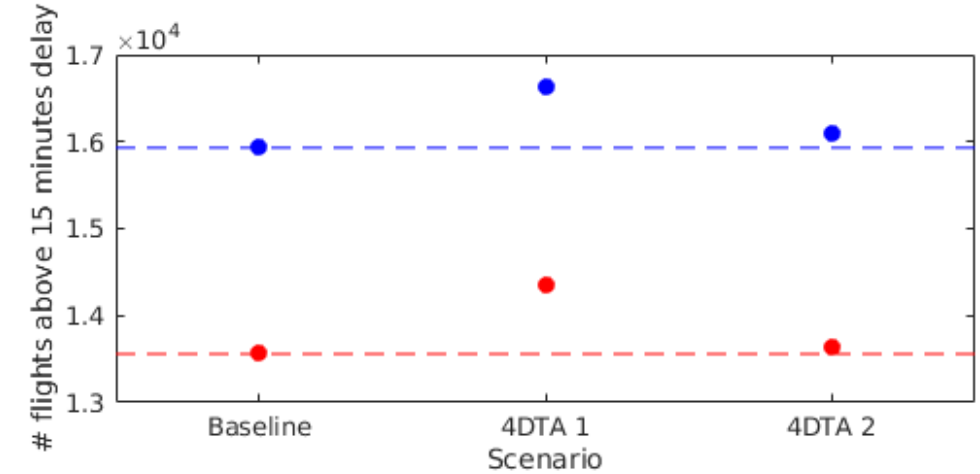
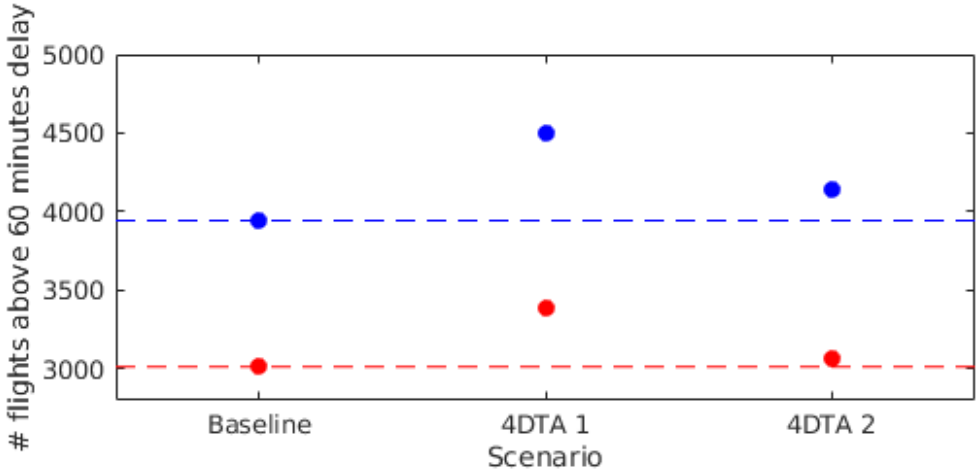
4D Trajectory adjustment

Delay -Tails

In stressed case:





- Departure delay
- Arrival delay (early arrivals counted as zero delay)

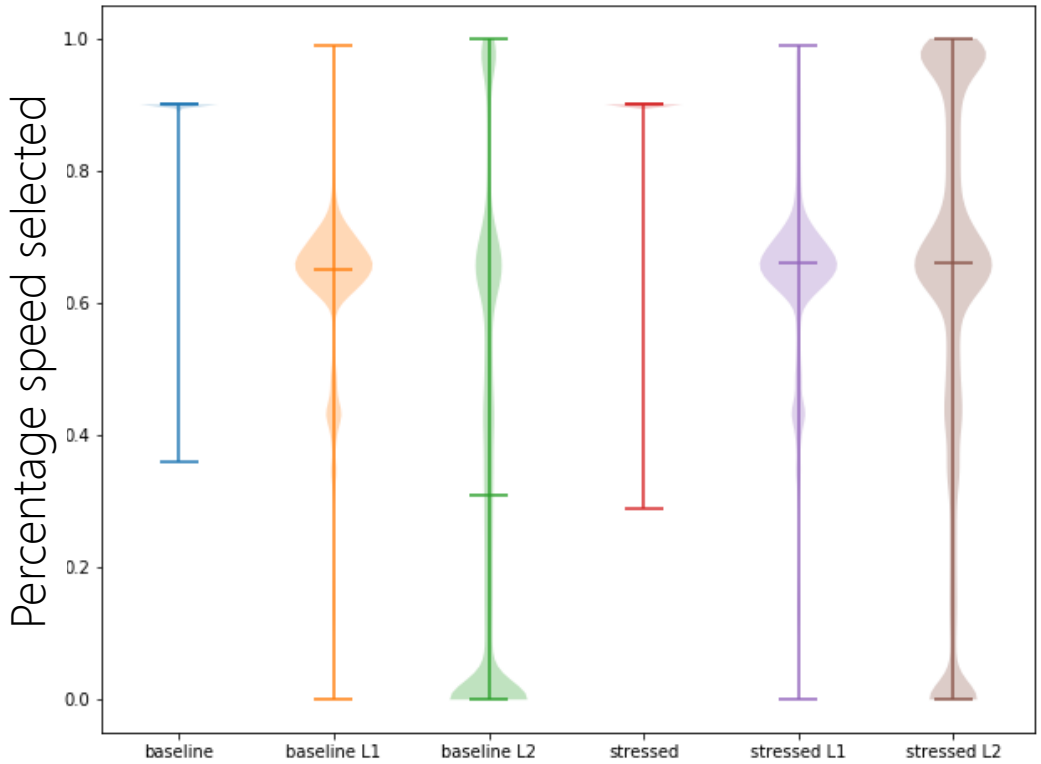
- # flights with delays >15, >60 minutes tend to increase with respect to baseline (especially at level 1)
- The average delay in these tails remains roughly the same

Interpretation:

- less speeding up to save fuel
- wait for passengers?

4D Trajectory adjustment

Speed adjustment



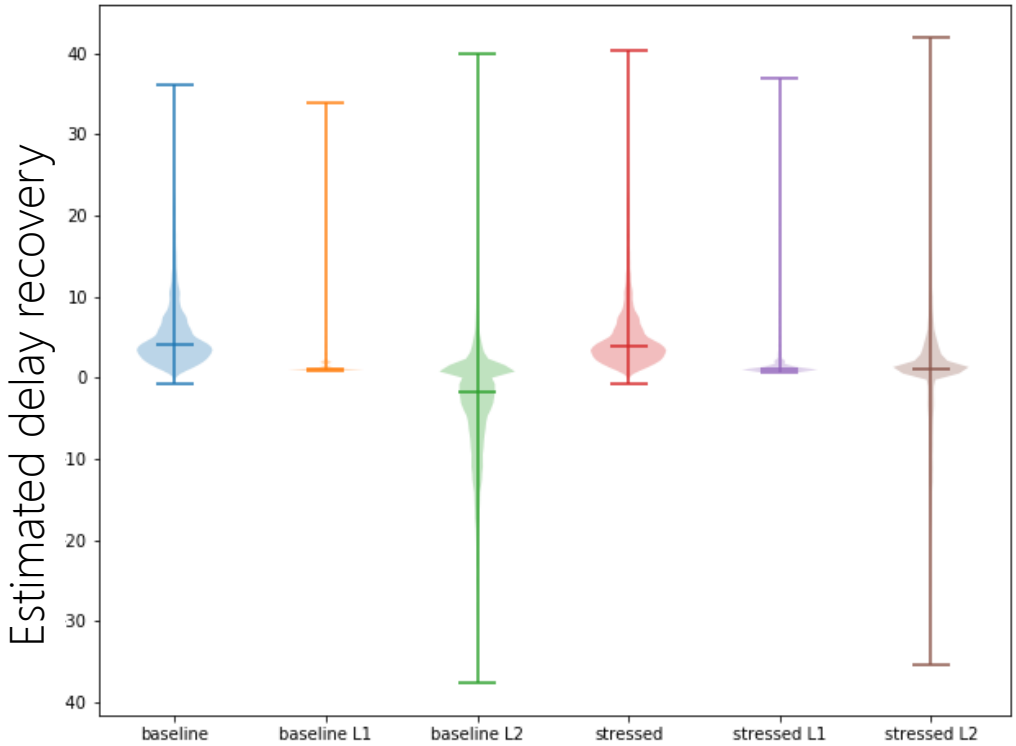
- Baseline: many chose 0.9 (maximum speed up)
- L1: some delay recovery ~0.7
- L2: Either some recovery, or extreme recovery, or saving

- Extreme delay recovery in L2 often reassessed at TOC

14%	12%	(43%) 11%	36%	11%	(18%) 10%	Percentage of delayed flights recovering delay

4D Trajectory adjustment

Delay recovery



- Baseline: ~5 mins
- L1: less recovery than baseline (~1 min), but no additional delay
- L2: more recovery than L1, but in the default case also creation of new delay

4D Trajectory adjustment

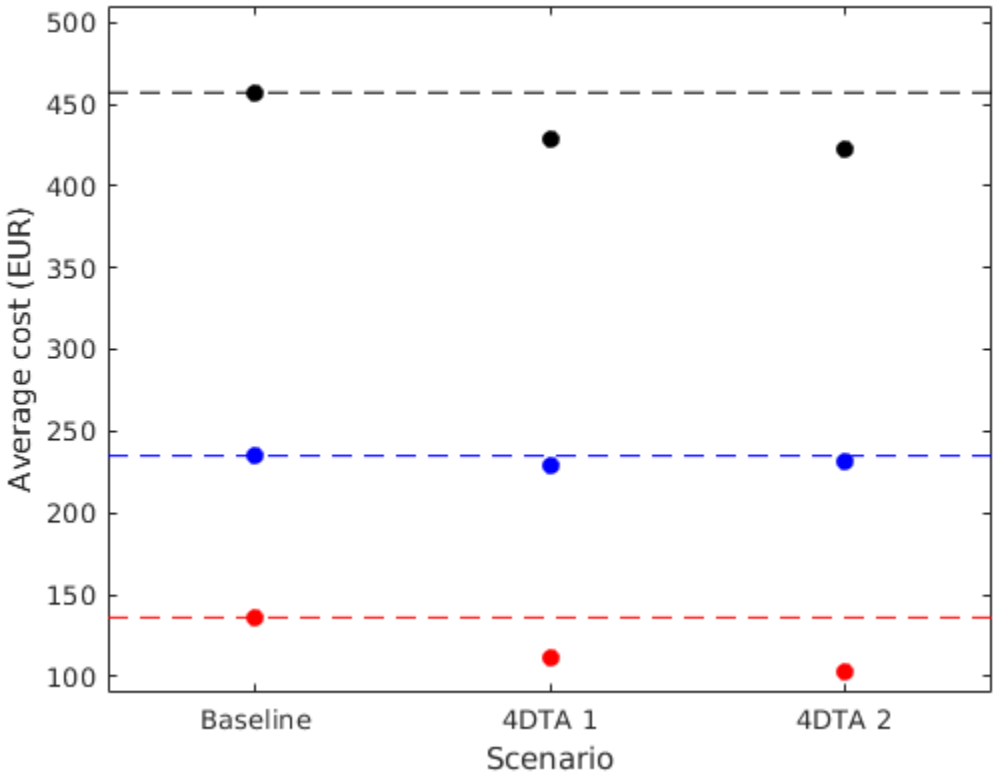
Costs

What do you expect to see?

4D Trajectory adjustment

Costs

In the default case:



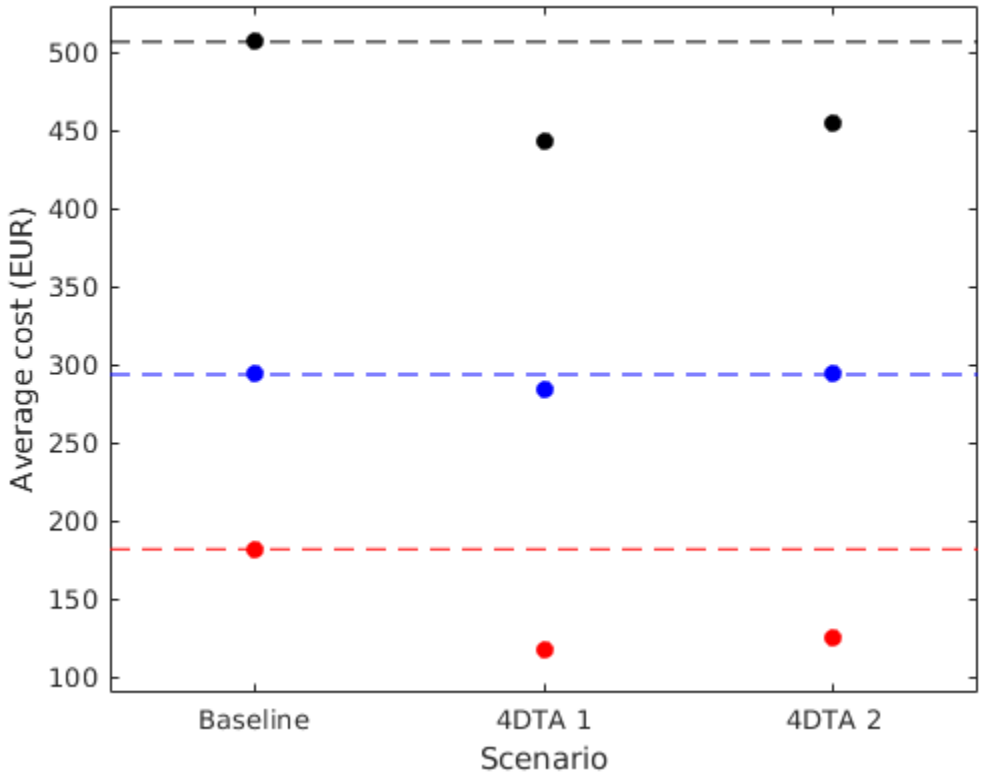
- Excess fuel
- Duty of care
- Total

(Costs not represented do not change significantly)

4D Trajectory adjustment

Costs

In the stressed case:



- Excess fuel
- Duty of care
- Total

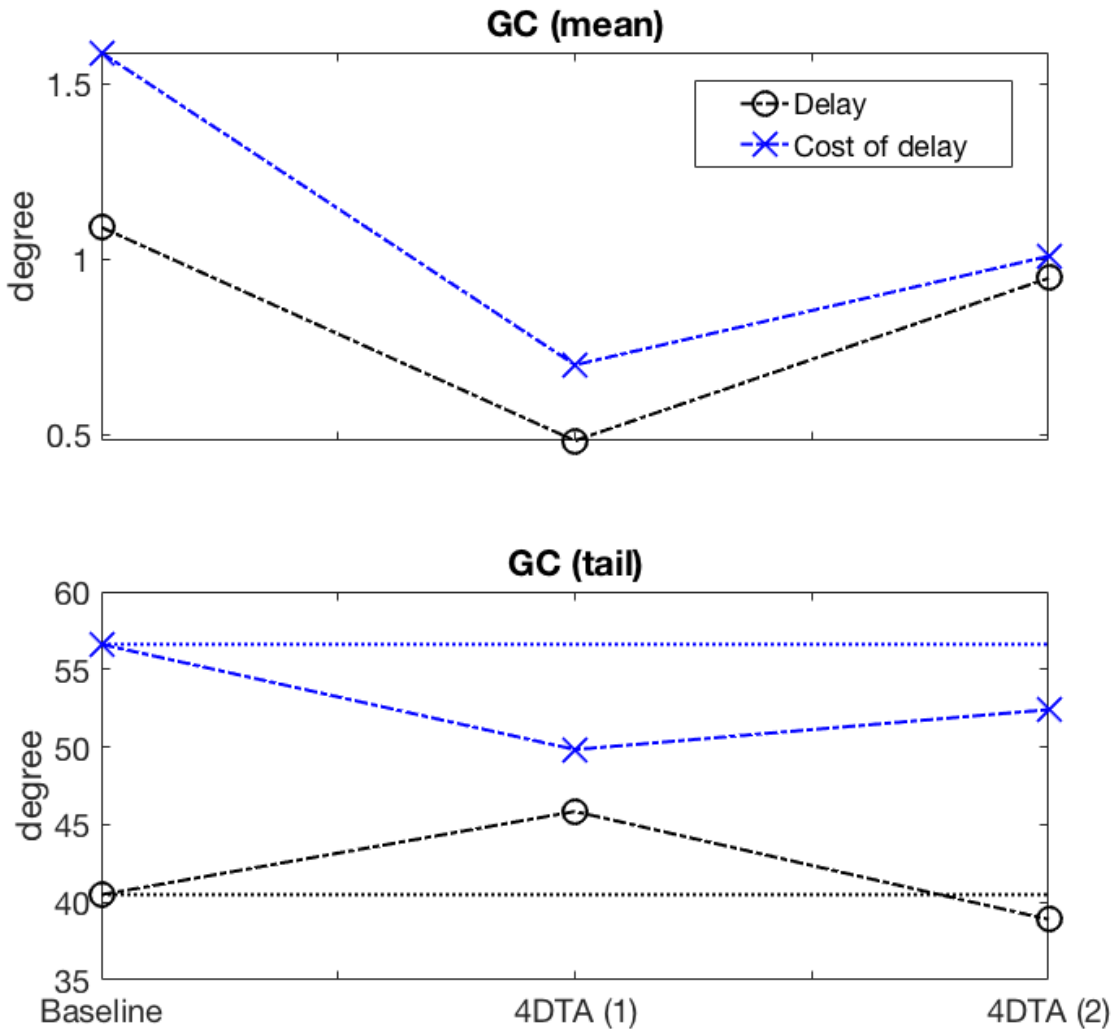
(Costs not represented do not change significantly)

4D Trajectory adjustment

Causality

In the default case:

- Extreme delays propagate more, or the same
- Average delay propagate less, or the same
- Average and extreme costs propagate less (better in level 1)



4D Trajectory adjustment

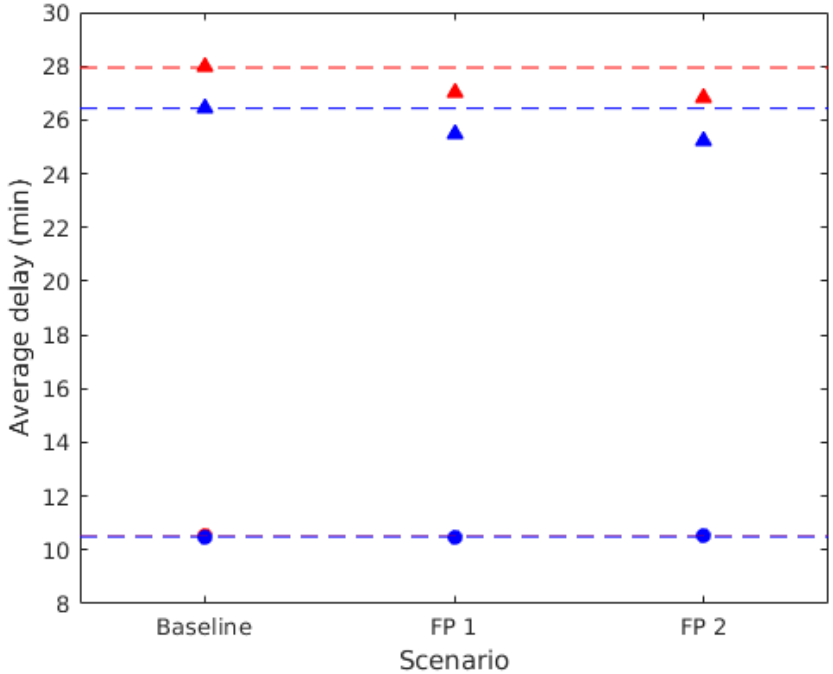
Conclusions

- Fuel is saved by speeding up less often
- As a result, average delays increase
- Also the number of delays in the tails (>15 min, >60 min) increase
- The change in passenger costs is negligible with respect to the change in fuel costs (also in the optimisation saving fuel is very often more convenient than avoiding passenger costs)
- It might be that in the optimisation we are underestimating the cost of delay related to curfew, and as a result flights slow down more often than they would realistically do
- We expect centrality metrics to show the possible negative effects of these increased delays on passengers (results not available yet)

Flight Prioritisation

Delays

Default:



- Departure delay
- Arrival delay (early arrivals counted as zero delay)
- Departure delay of flights subject to regulations
- Arrival delay of flights subject to regulations

- When considering all flights, no difference (in fact flights affected by FP are a less than 1%, ~100 flights in default scenarios, ~200 in the stressed one)
- When considering only flights subject to a regulation, a slight decrease of average delays, but often at the cost of increasing the number of delayed flights (especially in the stressed case)

Flight Prioritisation

Costs

- When considering all flights, no difference
- When considering only flights subject to a regulation, a slight decrease of average total costs in the default case, but in the stressed case level 2 increases the average costs (however, all changes are very small)

→ It seems that FP only induces a local benefit, which has no detectable effects at the whole system level in terms of delays and costs

In order to better restrict the analysis to the flights/airports affected by FP, and perform centrality and causality analysis as in the FAC case, we will analyse iterations where the regulations are fixed